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NOAA

Bob Williams

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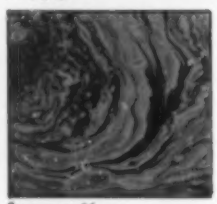
Story page 26

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Winter wonders

A Year Of Service

A review of the highlights of 1980 shows NOAA to be involved in events and situations that shape the everyday lives of Americans.

When Hurricane Allen threatened, forecasts and warnings helped Texans evacuate their southern coast with time to spare.

When Mount St. Helens erupted, several NOAA organizations mobilized immediately to measure its impacts upon humans, fish, the climate, and the environment.

NOAA looked to the saving of life and property with its coastal hazards program, with strengthened river and flood forecast programs, with a cold-water survival campaign that has won editorial acclaim. Our scientists are still at work on the effects of the Bay of Campeche oilspill, and prepared at a moment's notice to race off to the next threatening spill.

Our interests, of course, extend past human life to the protection of marine mammals. Because of NOAA's activities, the world's whales, porpoises, seals, and sea turtles are better protected than ever before.

The authority Congress granted us to develop and conserve the fisheries off our shores has resulted in turning back the tide of foreign encroachment upon our stocks—and in fact, the past year brought trade barrier reductions that promise $15 million in new business for American industry.

A major and relatively new thrust for NOAA is its growing involvement in the management of the oceans' non-living resources—gas, oil, minerals.

Six coastal state management programs received Commerce Department approval during 1980, bringing to 25 the states and territories with federally approved management schemes. A new marine sanctuary was created—the Santa Barbara-Channel Islands area off California. The number of estuarine sanctuaries rose to nine with the addition of protected areas in Florida, Oregon, and Ohio.

Other services moved steadily forward. We now make solar weather forecasts. Another GOES satellite has been launched, and we gained new responsibilities as manager of all operational civilian remote sensing programs from space. This includes development of a LANDSAT transition plan and shared responsibility with NASA and DOD in development of a National Oceanic Satellite System.

We placed in service a fine new vessel, the *Chapman*. We have issued 8½ million nautical and aeronautical charts. Our data services are used the world over. We are a focus for several vital national programs, including the National Climate Program and the National Marine Pollution Program.

It was our honor and pleasure to help bring into being the U.S.-Chinese program that culminated in an historic first: the research voyage of the *Oceanographer* to the shores of China—the first American ship to visit China in the 30 years that the People's Republic has been in existence.

And at the very end of the year, NOAA ships, aircraft and scientists collaborated with the University of Washington and with Canada in a novel effort called STREX—the Storm Transfer and Response Experiment. Out in the Gulf of Alaska in the foulest, most violent weather they could find, the investigators sought to learn more about the beginnings of the killer storms that sweep North America in the winter. The experiment employed the most sophisticated and innovative tools and techniques under the stress of a savage environment, to find some answers that will make safer and easier the lives of millions of Americans.

Not all of NOAA's work is carried out in hazardous conditions, and not all of it is in remote areas. But it is all designed to do what STREX sought to do—to help in a real and significant way the people we serve.

Boost to dry-suit diving safety

TRAINING DIVERS FOR BLOW-UPS

William J. Brennan

NOAA

NOAA

Bobbing helplessly on the surface (above), the diver who has experienced a blow-up may have ascended too fast, risking a deadly air embolism. With a weight belt still attached, the "blown-up" diver (right) presents an even more grotesque picture.

Loss of buoyancy control can be extremely dangerous to divers, but knowing what to do in such an emergency can prevent injury or possible death, a special team of NOAA divers has demonstrated.

Increasingly, because of the cold waters and areas of heavy pollution in which NOAA divers must operate, many of the agency's 400 men and women divers are wearing dry suits. Inflated with air or diving gas, these suits keep the diver drier than do the more traditional wet suits. But by their very nature, dry suits enhance the possibility of a "blow-up"—the loss of buoyancy control causing rapid, uncontrolled ascent to the surface.

"Our expanding use of dry suits made it desirable to investigate what might be considered diving folklore concerning blow-ups," Morgan Wells, NOAA's diving coordinator, said. "And we found we could do a lot of things experienced divers said couldn't be done with dry suits.

" 'You'll never pull that off,' we were told. 'You'll wind up on the surface flapping like a toad.' The surprising part is, no one did."

In a week-long exercise conducted at the Naval Surface Weapons Center's Undersea Weapons Tank at White Oak, Maryland, the NOAA team found that with proper training and techniques, an accidental blow-up need not become a life-threatening situation.

Inside the Navy's towering tank a few miles north of the Capital Beltway on New Hampshire Avenue in suburban Maryland, the NOAA team intentionally created blow-up situations in water depths as great as 100 feet.

"This exercise was potentially dangerous and normally would not be

done in open water," Wells explained. "But we felt compelled to duplicate as closely as possible conditions NOAA divers could face during operational activities, and attempt to develop techniques allowing the divers to be in control during a blow-up."

The dozen or so members of the team took with them to White Oak one of NOAA's "portable" recompression chambers in which to recompress divers should that be necessary. The chamber was hoisted to the top of the White Oak tank and temporarily installed there. Emergency use of the chamber was not necessary during the exercise.

One of the most common causes of dry suit blow-ups is loss of neutral buoyancy by a diver accidentally dropping the weight belt, a 30 to 40 pound belt worn to offset the positive buoyancy of the dry suit. Without such weights, a dry suit diver constantly would be struggling to stay at depth to conduct the work schedule.

Monitored by closed circuit television and with a safety diver alongside every moment, members of the NOAA team intentionally dropped their weight belts while 100 feet down in the tank. The normal, and safe, time of ascent from this depth is 100 seconds, following the standard one foot-per-second rate of ascent. In the blow-up situation, however, the divers rocketed to the surface as fast as five times the normal rate rising the 100 feet in only 20 seconds.

Should this occur to an untrained diver, the likely result would be death from an air embolism. The volume of air in a diver's lungs doubles as the diver rises from a 33-foot depth to the surface. Unless the diver controls the volume by exhaling all the way to the surface—thus reducing the volume of air in the lungs—air bubbles enter the blood, block one or more blood vessels, and interrupt normal blood circulation. The effect is the same as a stroke, and therapeutic action in the form of compression in a chamber must be taken immediately to prevent death or serious injury.

"During a blow-up situation, a diver must know what to do immediately," Wells said. "He or she has to start exhaling and attempt to maneuver into a position that will slow down the ascent rate.

"In a wet suit the diver has much better control over the rate of ascent. In a dry suit the air inside the suit expands as the diver rises, increasing the diver's buoyancy, and speeding up the ascent to the surface. This, in turn, increases the volume of air in the lungs at a faster rate."

NOAA diver Cliff Newell of the National Marine Fisheries Service Woods Hole Laboratories in Massachusetts,—a White Oak team member—faced this problem once during his career. Working at about 100 feet, he had increased the buoyancy of his suit to aid him in moving clumps of cement blocks from one location to another. Using a suit's positive buoyancy to assist in lifting heavy objects underwater is sometimes done by working divers. But it can have dangerous consequences, and it did this time. Newell lost his neutral buoyancy and slowly began rising.

The normal solution, according to Wells, would be to vent the suit, decreasing the buoyancy. Both of Newell's hands were holding the cement blocks, however, and he knew if he let go with even one hand—which he must do in order to vent—he would drop the blocks and rocket to the surface as a result of his increased buoyancy.

Newell did the only other thing possible, exhaling continually as he rose in the water. As the water pressure around him decreased, the volume of air in his suit increased, causing it to balloon. Only his awareness of the need to reduce the volume of air in his lungs by exhaling prevented his lungs from ballooning like his suit and probably causing an embolism.

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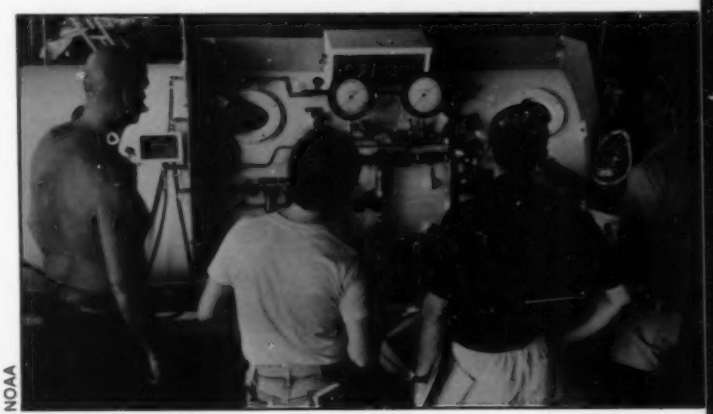

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A recompression chamber is hoisted to the top of the huge Navy tank (left) in which NOAA divers tested emergency techniques. The chamber (above), being inspected by some of the participants in the NOAA tests, provided an extra margin of safety—fortunately not needed.

As it was, the only damage to Newell was to his pride. By the time he reached the surface his suit had ballooned to more than three times its normal size and he floated helplessly on the surface until retrieved by tenders.

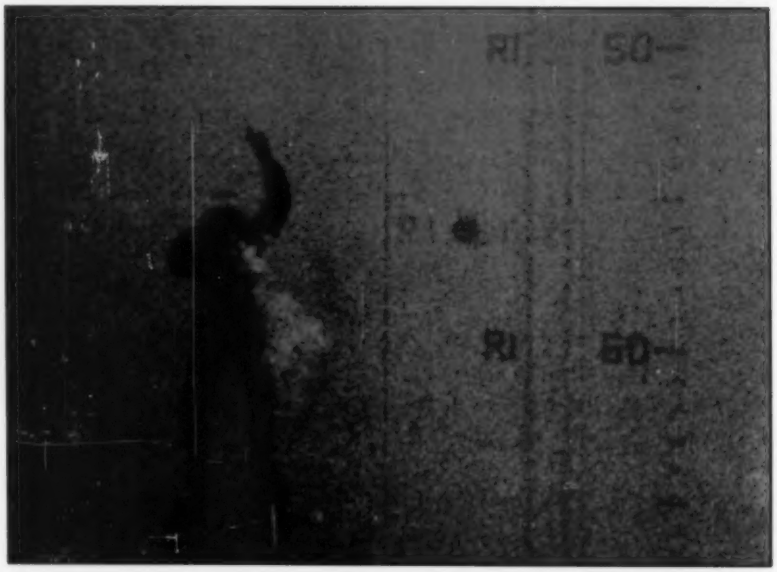
Dry suits have both an air supply valve and an exhaust valve. The supply valve in some suits is connected to the diver's air supply for inflation, while in other suits the diver must inflate them orally. The exhaust valve allows the diver to release air from his suit.

For the valves to do their jobs, as one NOAA diver learned, the diver must be able to control them. Sometimes, this isn't as simple as it sounds. The NOAA diver, on a work assignment beneath the surface, was wearing a chest-mounted "horse collar" buoyancy compensator; a harness-like life vest often used in concert with air in the suit to help a diver compensate for changes in buoyancy while working at different levels.

On this occasion, the NOAA diver chose to increase slightly the amount of air in his suit to change his buoyancy, rather than using the buoyancy compensator. He slipped his hand under the compensator harness and pressed the suit's air inlet valve. Instantly his suit began to inflate as air surged into it, pushing the back of his hand against the harness. He tugged, pulled, but was unable to remove his hand, still pressed solidly against the inlet valve. His suit ballooned as air flowed into it unimpeded. Shortly, he was bobbing about on the surface, his suit vastly over-inflated.

Again, awareness of emergency techniques prevented a serious, perhaps deadly, conclusion to the episode. The diver exhaled constantly en route to the surface, reducing the volume of air in his lungs and thus avoiding an embolism.

The "worst possible" dry suit blow-up situation for a diver is when he loses buoyancy control while working upside down, a not-uncommon position underwater. The air inside the suit accumulates at the highest point; in an inverted position, in the legs and feet, often pushing the diver's fins off. Before the chest or shoulder-mounted exhaust valve can function properly, the diver must maneuver into a positon letting the air in the suit flow to the chest area.



Closely monitored by television (above), a diver dangerously outraces his exhaust bubbles to the surface — a sign of too-rapid ascent. By assuming a "laid back" position, he is able to slow his ascent (right) as indicated by the bubbles which now appear above him.

Techniques to accomplish this were developed during the White Oak exercise and, additionally, it was learned that if a diver gets into a chest-up, horizontal position, not only can the suit's air be vented properly, but the rate of ascent can be slowed down as the amount of body resistance against the water is increased.

The blow-up exercise called upon the vast experience of a number of NOAA divers in addition to Diving Coordinator Wells and Fisheries' Newell. Among them were Dick Rutkowski, Director of NOAA's Training and Recompression Facility in Miami; and NOAA Corps officers Lt. Stanton Ramsey, Lt. Edward M. Clarke, and Lt. Cdr. Tom Ruszala.

Others were Michael Bergin of NOAA's Pacific Marine Center; Bill High of the Northwest and Alaska Fisheries Center; Robert Bedke and Robert Ellis, both from the Auke Bay Biological Field Station in Auke Bay, Alaska; NOAA photographer John Roseborough; and Barbara Brenkworth of the NOAA Diving Office.

In total, these NOAA divers have almost 200 years of professional diving experience, and in a number of instances have faced emergencies under actual working conditions that, improperly handled, could have taken their lives.

The week-long experiment specifically was to evaluate four different variable volume dry suits for:

- Causes of dry suit emergencies and failures;
- Ways to overcome such emergencies or failures;
- The suits' swimability;
- Flotation characteristics of the suits;
- Accessory equipment;
- Proper training techniques and development of a training curriculum.

Suits tested were the Poseidon Unisuit, the Poseidon Jet Suit, the Imperial Suit, and the Viking Dry Suit. Scores of conclusions and dozens of recommendations resulted from the exercise, many specific to the kind of suit worn and accessory equipment used. In general, however, perhaps the most telling conclusions are that emergency procedures for blow-up can be taught to divers, and that with adequate training divers should be able to respond to all blow-up emergencies, control their ascent rate, and prevent lung overinflation.

In other words, as a result of the NOAA research, a broadly held misconception has been laid to rest, and, it is hoped, the stage has been set for future diver training that could result in fewer accidents beneath the sea.

NOAA's exercise with, and testing of, variable volume dry suits contains important lessons to any dry suit diver, professional or amateur.

Possibly the most significant fact to emerge is that while dry suit diving does carry risks peculiar to the equipment used, these are not insurmountable. A diver can experience a blow-up without injury or loss of life, *if* the diver knows what to do in such an emergency.

The research has some pertinent points for dry suit divers:

- Procedures to follow during a dry suit dive can vary depending upon the model suit being worn.
- No one should engage in dry suit diving until having completed a special training course.
- While emergency blow-up venting procedures can be taught, this must be done under very controlled conditions.
- Ankle weights should be worn with dry suits when possible. They help keep the feet down in blow-ups, give stability, and help keep fins on in the event air gets into the suit's feet.
- When possible a quick-release shoulder harness should be worn with the weight belt to reduce the possibility of accidental belt loss.
- Front-mounted buoyance compensators should not be worn with any dry suit that has a purge valve on the front.

NOAA's Diving Office has developed a training curriculum outline for variable volume dry suit diving, applicable to both NOAA and non-NOAA divers.

Compare the fully-equipped diver (left) with those blow-up "victims" on page 6. There are times when an inflated suit is useful, however, as when it is blown-up on purpose (above) to assist in keeping an accident victim on the surface with his face out of the water.

VIEW FROM SPACE

Unchecked Fires Rage In California

Los Angeles Times

Last November, Nature dealt another in a series of blows to suburban areas of Los Angeles nestled among the hills and valleys east of the city. An extended dry spell, Santa Anna winds, and high temperatures created a tinder box of the scrub-studded area. A spark ignited it, and yet again the area experienced devastating brush fires as it has so many times in the past.

The mid-November fires were the worst in several years, devouring scores of expensive homes and causing damage that totalled in the millions. In some areas entire neighborhoods were levelled (above) as the flames, pushed by the winds, jumped from one luxurious home to another. Hundreds of persons were evacuated from threatened areas, some to see their homes and possessions spared either through the efforts of fire fighters or the capriciousness of the winds. Others were not so fortunate; flames created mounds of rubble from what only a few hours before had represented the culmination of family dreams (Picture #2).

Los Angeles Times

Los Angeles Times

The task of fighting the fires was an awesome one, pitting mere mortals against natural forces that threatened to overwhelm them. But the battle was fought, frequently in single-handed fashion (Picture #3) as the ranks of the fire fighters were thinned by exhaustion. And this time, again, the fight was successful, in so far as eventually containing the flames before they consumed square miles of residential areas is concerned; small consolation to those whose homes were in the midst of the battleground and were destroyed.

Throughout the days and nights when flames danced across the hills, and smoke billowed into the sky, NOAA's West Coast GOES satellite stared dispassionately down at the near-holocaust 22,300 miles below. Every 30 minutes GOES-West imaged the earth beneath it, and those privileged to view the imagery saw the extent of the Los Angeles fires as witnessed by the expanse of smoke they produced. Picture #4 is a standard visible picture; in black and white what an astronaut would see were he in orbit at the altitude of the NOAA spacecraft. Picture #5, imaged at sunrise on November 16, an hour earlier than Picture #4, has been enhanced by specialists with NOAA's National Earth Satellite Service to make the smoke more visible. Due to the offshore flow of very dry air, all of the cloud-like matter in the Los Angeles area and over the water west of the city is smoke and not clouds.

The images are obtained from radiometers aboard GOES-West; instruments which sense reflected light, electronically transmitting what they "see" to an Earth station where computers create the picture.

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Stress on STREX

IN NATURE'S ICY CAULDRON

Carl A. Posey

There has been much meteorology in literature, from the storms that took Odysseus off course to all the crackling and wailing that comes with hard times in stories like *Macbeth*, Conrad's *Typhoon*, and the rainy weather in Maugham. There has been less literature in meteorology, a notable example being George Stewart's 1941 novel, *Storm*.

That fictionalization of a large, mid-latitude disturbance he called Maria has become a classic, not so much for its style or its meteorology, as for its view of the atmosphere. For *Storm* sees global linkages; atmospheric dominoes begin to fall over Russia, and topple sequentially across the world for weeks afterward. On its long eastward drift, Stewart's atmospheric protagonist enters the Gulf of Alaska, the cauldron where nature forges elements of weather which not only spin into maritime storms, but come to dominate the North American atmosphere for days and weeks at a time.

Now, scientists from the United States and Canada have taken instrumented buoys, ships, and aircraft into that violent cauldron, to take the measure of the actual act of forging such weather—and to learn more about how to forecast those processes, and the way they drive climatic changes. These storms, which have the appearance of out-sized hurricanes, offer these investigators a set of environmental conditions as severe as any in the hemisphere.

Called STREX (for Storm Transfer and Response Experiment), the study focuses on the exchanges of energy, momentum, and water vapor across the ocean-atmosphere boundary extending from several thousand feet in the air to several hundred feet beneath the sea.

The experiment is managed jointly by the National Oceanic and Atmospheric Administration, the University of Washington, and the Atmospheric Environment Service of Environment Canada. But STREX is viewed by its protagonists as an international cooperative experiment organized as a federation of principal investigators drawn to the experiment for independent—but complementary—research.

Responsibility for the direction of the project rests with Dr. Robert Fleagle of the University of Washington, and Dr. John Apel, who directs NOAA's Pacific Marine Environmental Laboratory in Seattle. Their decisions are guided by a STREX Executive Committee of American and Canadian scientists.

"Atmospheric dominoes" in the Gulf of Alaska

A project office in Seattle was established to provide cohesion between the logistically complex experiment and the various principal investigators, and to guide the day-to-day operations of STREX. The project office is headed by Dr. Mikio Miyake, of the Institute of Ocean Sciences in Victoria, B.C., and NOAA Cdr. Edward M. Gelb.

The field phase of the experiment began October 5, with the air deployment of NOAA buoys by the U.S. Coast Guard, and ended when the weather ship *Vancouver* returned to Esquimalt, B.C., in mid-December. During that interval, periods of intensive observation—periods when research aircraft joined the ships to probe major storms—were carried out in early November and early December.

The first mission for *Parizeau*—a Canadian research ship—was to deploy drift buoys in the STREX study area, permitting them to drift with the storms probed by the investigation. The 240-foot ship made a second voyage to obtain oceanographic measurements in the STREX area during November.

Meanwhile, early in November, the 404-foot Canadian weather ship *Vancouver* sailed for ocean weather station Papa, at 50 degrees north, 145 degrees west. The *Vancouver* carries an advanced five-centimeter-wavelength cloud radar, providing a digitized view of storms forming in the STREX area. Images from the ship's radar were transmitted directly to the STREX Project Office, and used in a real-time mode to shape daily operations.

Also in early November, the NOAA research vessel *Oceanographer* sailed from its Seattle base to take up a station four and a half degrees east of the *Vancouver*, at 50 degrees north, 140.5 degrees west. The *Oceanographer* deployed four moorings in the area, carrying sensors to measure variations in temperature with depth, from the surface to the sea floor.

Once the moorings were in place,

researchers on the NOAA ship from the Pacific Marine Environmental Laboratory and the University of Washington conducted time-series measurements on station, and sampling legs in a triangular pattern around the station. The object here was to monitor the internal structure of the sea as storms passed the ship, to determine the degree to which the ocean "feels" the passage of a large maritime storm, and to identify some of the oceanic processes accompanying such passage—for example, the occurrence of an underwater density discontinuity, or "front," corresponding to fronts in the atmosphere.

According to Dr. John Apel, the experiment is the first in which such systematic measurements have been made in Gulf of Alaska storms.

"A number of studies have been done in nice tropical weather, but there's been very little work done in these large mid-latitude storms," he said. "In STREX we actually have ships taking measurements inside the storm, and airplanes probing the atmospheric boundary layer in and around the storms. So we'll be operating under conditions where very little by way of scientific measurement has been attempted."

While STREX looked mainly at the flow of energy and momentum from the ocean into the atmosphere, Apel pointed out that the experiment should also bring new insights into the atmosphere-to-ocean exchange.

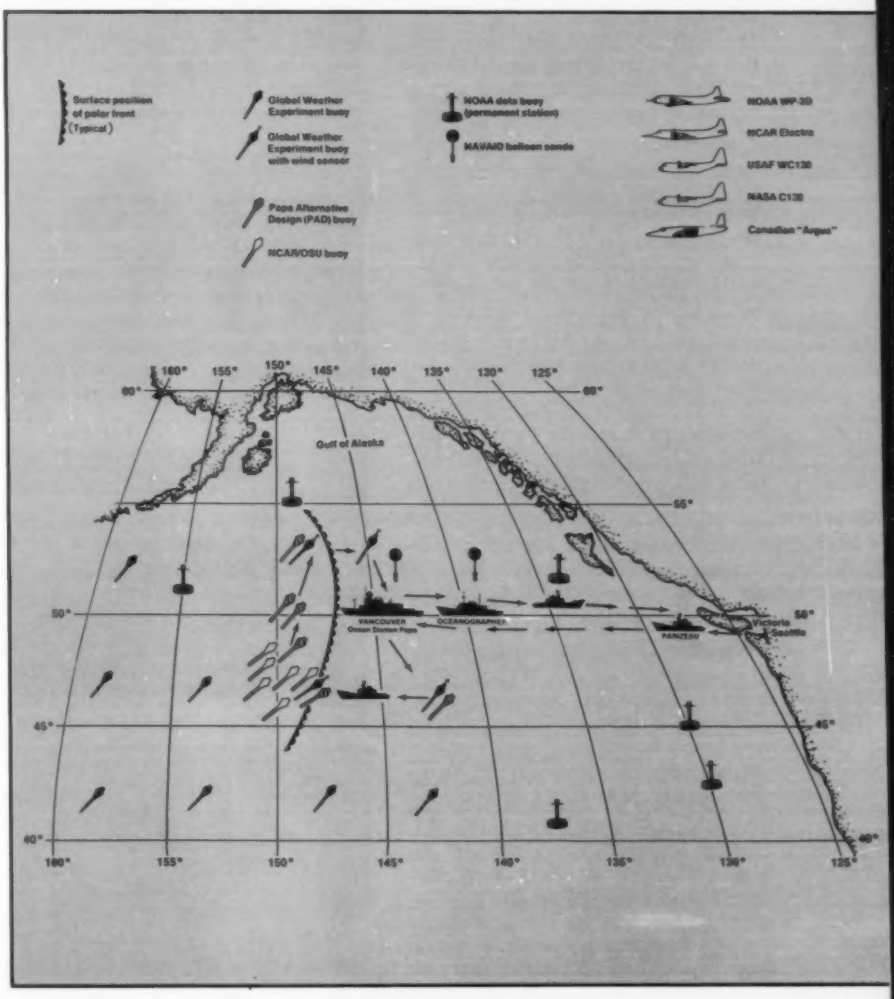
"Theoretically," he said, "the ocean is driven by wind, the rising of heavy water and the sinking of light water. But we have no clear idea of how deep currents come out of surface winds."

Both the *Oceanographer* and *Vancouver* took a variety of routine meteorological observations, as well as upper-air measurements with the "Navaid" balloon-sonde system developed for 1979's Global Weather Experiment. The balloon-borne instrument package senses weather elements, such as temperature and humidity, and its own position relative to the Omega global navigation system. This information was relayed to NOAA satellites in geostationary orbit some 22,000 miles above the equator, and subsequently passed to ground stations operated by the National Center for Atmospheric Research and Colorado State University. Scientists there processed the sonde data in real time, converting it to "Shiptemp" messages for the STREX Project Office in Seattle and worldwide distribution via the Global Telecommunications System.

"We are phasing out our weather ships in Canada," explained Dr. Miyake, "and hope to replace them with sondes and buoys which we will be testing in STREX. This is the last winter for ocean station Papa, so it is also our last opportunity to take these measurements with the weather ship in place."

Miyake added that weather information from the Gulf of Alaska is crucial for Canadian meteorologists, possibly more so than for their American colleagues.

"The type of storm we're talking about enters the continent be-



A variety of instrument platforms are used for STREX. Ships, aircraft and in-place buoys were augmented by a buoy deployment mission (indicated by arrows) undertaken by the Canadian ship Parizeau.

tween about 50 and 60 degrees north. But the United States has many doors storms can enter. In western Canada, we have that one door—all of our storms enter through that ten-degree band."

Because the measurement routines of the experiment had to be carried out under severe environmental conditions, STREX has stimulated the development of special techniques for obtaining necessary data during violent Gulf of Alaska storms.

These conditions can be very severe indeed, according to Cdr. Gelb, STREX operations manager. "In STREX, we're placing aircraft and ships into a very harsh environment, where we can expect winds as high as 60 knots, and two-story seas," he said. Gelb notes that as many as ten storms could be expected to churn through the experiment's array during the 6-week period of the study.

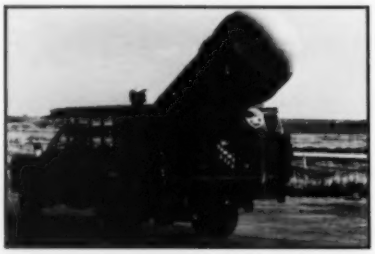
"From an operational standpoint, this will be very trying for the people involved, especially shipboard personnel who will be out there for an extended period."

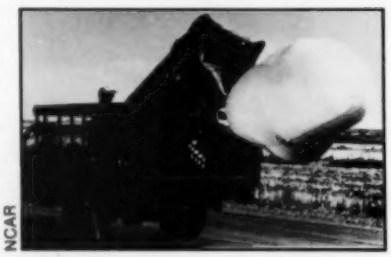
In order to launch the Navaid balloon-sondes during storm condition, a special balloon-launcher was developed by NCAR. The new launcher is a fiber glass tank rigidly attached to the ship's deck. As the balloon is inflated inside the tank, a fabric cover constructed like a camera lens shutter (or the iris of an eye) rotates open, and a low-pressure air blower at the base of the tank forces the balloon out. As the balloon rises it lifts the sonde package from a dispenser on the tank's exterior. (One NOAA observer commented that this kind of balloon launch resembled a live birth.)

Oceanographers aboard the ships also had some new tools of the trade, some of them especially designed for use in the difficult environment of maritime storms. This permitted the scientists to take conventional measurements to determine how the ocean behaves under a major storm, without the hazards of having the heavy gear of conventional oceanography battering itself and the ship in heavy weather. A large sensor package swinging on a cable in heavy seas is the modern day equivalent of a runaway cannon on the deck of a rolling galleon.

Many of the new instruments are expendable. Expendable bathythermographs, used for some years now to obtain thermal profiles of the ocean from both research and merchant vessels, were employed, complementing the airborne units launched by STREX aircraft. But some of the newer systems take much more complex measurements than the time-tested XBT. For example, an expendable velocity profiler permits scientists aboard to measure underwater current velocities from the surface to more than two thousand feet. The device, developed by a scientist now with the University of Washington, senses the minuscule electric field set up by the passage of the ocean water through the earth's magnetic field.

This "cannon," shown in tests, helped to launch weather balloons in rough seas. The expanding helium balloon is forced from the muzzle by air in the barrel.





NCAR

Other innovations include expendable CTD's, which measure the water's conductivity, temperature, and density down to several thousand feet, permitting oceanographers to calculate the density surfaces which determine ocean currents. The Canadian equivalent of this is a miniaturized CTD, a small system that can be deployed safely in rough seas, and towed by the ship.

The STREX buoy program began with the October deployment, by a U.S. Coast Guard aircraft, of seven drifting buoys of the type used during the Global Weather Experiment. These, and four more buoys of this type carrying a newly developed wind sensor, were contributed by the NOAA-operated Global Atmospheric Research Program (GARP) project office in Washington. Data from these buoys complemented other STREX observing systems, as well as providing data for operational weather forecasters and to support the climate research programs of the World Meteorological Organization.

Two other buoy systems were tested in STREX.

One is called the Papa Alternative Data System, or PADS, under consideraton as an alternative means of gathering the surface data now taken by Canadian weather ships. Four drogued and two free-floating buoys were deployed near ocean station Papa during the first cruise of the *Parizeau*, to measure atmospheric pressure and sea-surface temperatures. The hope is that a combination of these buoys, Omega sondes dropped from Canadian patrol planes, and Navaid balloon-sondes launched from merchant ships of opportunity could do less expensively work now done by weather ships.

A third buoy system was part of a NCAR-Oregon State University air-sea interaction experiment. An array of six buoys took pressure and sea-surface temperature readings, which also measured temperatures at ten intervals, and hydrostatic pressures at three intervals, along a 360-foot (120-meter) thermistor chain, which serves as a drogue for the drifting buoy. Deployed by the *Parizeau*, the buoys should help NCAR and OSU investigators document the temperature and velocity responses of the upper ocean to forcing from passing storms.

All the drifting buoys used in the experiment reported their measurements and positions to passing NOAA polar-orbiter satellites.

A squadron of research aircraft from a number of organizations did much of the special data-gathering during the intensive periods of STREX. Aircraft used in the study included a WP-3D Orion from NOAA's Research Facilities Center in Miami; NCAR's Electra; a WC-130 "Hurricane Hunter" from the 920th Weather Reconnaissance Group, Keesler Air Force Base, Miss.; a C-130 from NASA's Langley Research Center, Hampton, Va.; and a Canadian Air Force "Argus" aircraft, from Comox, B.C. In addition, a second Air Force WC-130 from the 53rd Weather Reconnaissance Squadron, Keesler Air Force Base, and a Navy P-3 out of Moffett Field Naval Air Station, Calif., gathered incidental data for STREX while on other patrols.

Operating out of the Seattle-Tacoma area, the STREX aircraft launched when storm conditions were forecast for the Gulf of Alaska. The Air Force C-130 provided a high-altitude platform from which to deploy Omega drop-sondes—parachute-borne instrument packages which measure weather elements as they drop through the atmosphere, sensing their position relative to the Omega global navigation system.

NOAA's Orion joined the C-130 for high-altitude work. But it was also an important boundary-layer platform, along with the NCAR Electra. Both of the aircraft are equipped to take comprehensive atmospheric measurements, and carry gust probes that permit investigators to sample heat and water vapor fluxes in the undisturbed atmosphere a few feet ahead of the airplane. In effect, these aircraft probed the region where the central interactions of the study occur—the lower thousand feet or so of the atmosphere. Both airplanes launched Omega dropsondes to profile the atmosphere from flight altitude to the sea surface.

The NOAA P-3 also performed as an oceanographer's platform, dropping airborne expendable bathythermographs (AXBT's) on most missions. AXBT's are used to profile the ocean's thermal structure from the surface to depths of a few thousand feet. After the air-dropped cannister opens on impact with the water, an instrumented probe continues to dive through the water, linked by a wire to a floating antenna portion of the probe. Data from the sinking probe is radioed directly back to the aircraft computer, and presented to mission scientists in real time.

The Canadian Forces Argus aircraft also provided AXBT support to the experiment, deploying the probes during its regular patrol missions over the Gulf of Alaska. Further AXBT support came from a Navy P-3 operating out of California.

The type of mission flown by aircraft for STREX depended upon the location of the main polar front associated with the storm being studied. Aircraft flew a wide variety of patterns ahead of, through, and behind the fronts, as they crossed the STREX surface array of ships and buoys.

Both the NOAA P-3 and NCAR Electra flew low-level missions, some within 150 feet of the sea surface. In addition to normal data-taking, the P-3 measured wave height with its precise laser profilometer, and wave length and directions with a side-looking imaging radar.

The NASA C-130 used its radar scatterometer, microwave radiometer, and synthetic aperture radar—remote-sensing devices similar to those planned for ocean-watching satellites—to observe sea surface characteristics such as wind speed, ocean temperatures, and wave patterns. This information was complemented by the wave spectra profiles from the NOAA P-3.

Visible and infrared imagery from NOAA's western geostationary operational environmental satellites—GOES-west—and polar-orbiting satellites were received in facsimile at the Seattle office of the National Weather Service. Geostationary images were available every half hour during STREX, aided by a team at the Redwood City, Calif., facility of the National Earth Satellite Service. This kind of data was used by STREX managers to guide the experiment, and to provide an environmental context for assessment of results when the experiment ends. Upper-level winds will be obtained from the satellite images by scientists from the Universities of Washington and Wisconsin.

The satellites also acted as go-betweens for data from buoys and the atmospheric soundings made from the *Oceanographer* and *Vancouver*. Buoy measurements and positions were relayed by polar-orbiting satellites to ground stations, where the information was processed in near real time and put on the Global Telecommunications System for worldwide distribution. Sounding data from *Oceanographer* and *Vancouver* were relayed to Colorado ground stations by GOES-west, and turned into Telex messages, providing sonde data on winds, atmospheric vertical structure, and ship position.

The mountain of data collected during STREX will be archived in easily accessible formats at the National Climatic Center, in Asheville, N.C., and the Atmospheric Environment Service Climate Center in Downsview, Ontario. STREX scientists will compare their preliminary findings in a seminar in Seattle in mid-1981.

Dr. Robert Fleagle, one of the co-directors of STREX and former head of the Department of Atmospheric Sciences at the University of Washington, may have the most succinct definition of the experiment's objective.

"The scientific interest in doing an experiment like STREX comes from our view that the ocean and atmosphere are coupled," he said. "Predicting the behavior of either on the scale of weeks, seasons, or perhaps even a year requires that we understand how heat is released from the ocean to the atmosphere. We have reason to believe a lot of that heat is released in storms, but this has not been studied very extensively because of the practical difficulties of taking measurements under such conditions."

While STREX is not the first study of its type—there have been similar studies in other winter oceans—it is unique in the degree to which it focused on the mid-latitude storms crossing the Gulf of Alaska. For this investigation studied, as few others have, some of the critical linkages in the intricate system of global weather, the actual moment of collapse of atmospheric dominoes, at a point where processes are set in motion that come to pervade the life of every North American.

CITY SCAPE

Niagara Falls Shooting the Rapids

Monday morning, September 29. Lt. Cdr. Richard Muller at the controls of the Rockwell Turbo Commander 690 dropped to 1,500 feet as he approached Niagara Falls.

"Let's take a couple of obliques," he said to photographer Harvey Carlson who aimed the Wild RC8 aerial camera at one of the most spectacular sights on the continent.

Pilot mission chief Muller, Carlson, and co-pilot and navigator Lt. Cdr. Pat Wehling were on a National Ocean Survey nautical chart revision project to obtain aerial photos of the Niagara River and the south shore of Lake Ontario for the NOS Office of Marine Surveys and Maps.

The Mission 1 photo shows the American Falls (left center) and the Horseshoe Falls (far right) on the Canadian side of the Niagara River which plunges 500,000 tons of water a minute into a steep-walled gorge. Linking New York State and Ontario is the 960-foot Rainbow Bridge (far left) on which six million annual visitors step across a

U.S. Travel Service

painted boundary marker—not one soldier stands guard along the 3,987-mile U.S.-Canadian border.

Observation towers on both the American (upper left) and Canadian side (far right) and two Maid-of-the-Mist ships offer countless visitors an unforgettable view of the Falls where, legend says, Indians each year sent their fairest maiden over the Falls in a canoe to appease the Thunder God living below.

Today, the waters of the Niagara River have been harnessed for generation of power, some four million kilowatts. A 1950 hands-across-the-Niagara treaty gives Canada and the United States an equal share of the waters as well as prescribing a minimum flow over the Falls. To measure the water level of the Niagara and to record the amount of water used for power diversions, U.S. and Canadian water level gages have been installed above the Falls and below the Rainbow Bridge.

The NOS Water Levels Branch continuously monitors the level of the Niagara for compliance to the 1950 Treaty. The Treaty prescribes a minimum flow over the Falls of 50,000 cubic feet a second except in daylight during the tourist season, when it is increased to 100,000 for esthetic reasons. Records indicate that the amount of water flowing over the smaller American Falls (upper right) averages about 9,300 cubic feet per second.

The Maid-of-the-Mist (far right) travels along the bottom edge of the American Falls where rock slides are causing a continual erosion.

Grand Island Daily Independent

Acid test at Grand Island

NOAA WEATHER RADIO: LIFE SAVER

Don Witten

"Our windows and drapes were closed. The record player was turned up high and the air conditioner was on. We had no idea of what the weather was doing.

"The first we knew of any trouble was when the weather radio automatically came on with a severe thunderstorm announcement. As conditons rapidly worsened, a tornado warning was issued and the forecaster advised us to take cover."

Valerie Lloyd of Grand Island, Nebraska, was describing a night of terror for her and her husband Bob. They had moved into their new home in Grand Island just 4 days earlier. Then, on the evening of June 3, 1980, seven tornadoes struck the area.

"The tornado sounded like a train coming right at us. My husband and I couldn't hear each other yelling even though we were huddled side by side in a 3-foot-wide closet under the steps.

"It got real quiet and we felt a lot of pressure in our ears, like when you are in an airplane. Then it hit. The windows went first. Seconds later, the whole house was ripped apart, along with most of our belongings," said Mrs. Lloyd.

"One of the few things we did salvage was our weatherband radio which we had taken into the closet—still operating on batteries. We will cherish it forever; it literally saved our lives.

"We received the weather radio as a gift from the United Bank Services Company in town," she added. "I remember thinking at the time that the radio was useless. Needless to say, I've never been more wrong about anything in my life."

The tornado warnings broadcast in Grand Island that June evening originated in the National Weather Service Office abouty 3 miles from the Lloyd's home. This office operates one of the approximateiy 350 stations in the NOAA Weather Radio system, a network whose broadcasts are within monitoring range of nearly 90 percent of the Nation's population. Each station broadcasts localized weather forecasts and warnings directly to home receivers, around the clock.

"The weather in Grand Island that evening could not have been more severe. It was a record-setting storm,"

"...it literally saved our lives."

according to Donal Davis, Meteorologist-in-Charge of Grand Island's Weather Service office.

"A massive thunderstorn system moved over the area at about 7:30 p.m., remaining there—often stationary—for about 3 hours. One after another, tornadoes spun down like rotary buzzsaws, cutting paths of destruction and injury across the city and suburbs.

"In all, seven tornadoes struck Grand Island—the largest number ever to hit one city in a single storm. One monster tornado in the storm had winds estimated at over 250 miles an hour," said Davis.

Several times during that hectic evening, tornadoes severe threatened to crash directly through the Grand Island weather office and put it out of operation.

After the massive storm moved southeastward, five people lay dead and some 200 others were injured in the Grand Island area. Property damage amounted to $300 million. Over 700 homes and businesses were destroyed and another 3,000 buildings were damaged. The heaviest destruction was concentrated in the south central area of the city where Bob and Valerie Lloyd live.

"There is no real way to estimate how many injuries or deaths were prevented by the NOAA Weather Radio broadcasts. However, these broadcasts were an essential part of our warning effort that night," Davis said.

Others in Grand Island agree with Davis. Roger Dodson, General manager of AM/FM radio station KRGI, tells the following story:

"At 10:20 p.m., twin tornadoes—one of them the monster—moved together down Locust Street, devastating the city's main power system. Our broadcast studio went dead, but the transmitter to the south was still operating.

"The floors of the transmitter site were awash with rainwater, and lightning was crackling everywhere. Despite the constant danger of electrocution, our chief engineer and coworker labored feverishly to stay on the air. They finally managed to patch the NOAA Weather Radio broadcasts into KRGI's transmitter. As a result, we were able to rebroadcast the tornado warnings and follow-up information," Dodson recalled.

Grand Island, Nebr., after the June 3 tornado outbreak (facing page) was a shambles, but NOAA Weather Radio operations (right) played a major role in keeping the death toll low.

NOAA

"Without a doubt, the Grand Island incident and particularly the Lloyd's dramatic story, clearly reveals the highest value of the NOAA Weather Radio system: the protection of human life during severe weather," said Dr. Richard E. Hallgren, Director of the National Weather Service.

In addition to severe weather warnings and routine forecasts, NOAA Weather Radio broadcasts specialized information, tailored to the particular locale. Transmitters along the coast, for instance, give marine forecasts and observations, while some of those inland may offer agricultural information such as soil temperature, humidity, and percentage of sunshine.

NOAA Weather Radio receivers can be found throughout the country on the desks of civil defense directors, high school principals, business executives, and county officials. Some farmers keep them in their homes and barns while others carry the receivers into the fields. Recreational use is varied. Boaters, hunters, campers, and travelers monitor the direct weather broadcasts nationwide.

Just how many Americans can tune into the NOAA Weather Radio broadcasts?

Merchandising Magazine, an authoritative trade publication, provided the following:

"Sales figures for 1978, 1979, and those projected for 1980, show that U.S. distributors annually purchased an average of nearly nine million radios capable of receiving the direct weather broadcasts," said Editor Ron Schneiderman.

Nearly 80 percent of these sales were for the new multiband radios which can receive AM and FM radio, TV audio, and weather. The remaining sales were divided about equally between weatherband units which offer weather broadcasts exclusively, and scanner units which monitor weather, police, and other frequencies.

The concept of continuous weather broadcasts by the National Weather Service initially was tested in the early 1950's. A Chicago station was the first on the air in 1953, followed by a second station 3 years later in New York City.

During the next 20 years, the direct-broadcast system was extended along the coasts, principally to serve recreational boaters, commercial fishermen, and others engaged in marine activities. In this period, the network also was expanded inland near some of the larger metropolitan areas to provide continuous weather information for the general public.

By the early 1970's, a national plan called for the major expansion of the radio network. Today, most of the proposed 350 stations are in operation.

Each weather station has a broadcast range of about 40 miles. The quality of home reception depends upon the type of receiver used, antenna height, and local terrain. Tall buildings and mountains can hamper reception. To minimize interference between any two stations, the broadcasts are transmitted on three VHF/FM frequencies. They are: 162.40, 162.475, and 162.55 megahertz—frequencies much higher than the 108 megahertz range designated for commercial FM radio.

350-Station Network Nearing Completion

The weatherband radio owned by the Lloyd's of Grand Island is one type of consumer-grade receivers designed to monitor the weather broadcasts. Their unit, valued at $40, has a special alarm feature not available on less expensive models. If this unit is turned on and the "alarm only" switch flipped, it will silently monitor the weather broadcasts. The receiver's volume automatically becomes audible only when the weather office transmits a special signal, preceding a storm bulletin.

Some of the alarm-equipped units sound a loud signal to notify the listener to turn on the weather radio for a special announcement.

Due to this unique capability, the White House designated NOAA Weather Radio as the sole government-operated radio system to provide direct warnings into private homes for both natural disasters and nuclear attack. This capability supplements warnings by sirens and commercial radio and TV.

In the future, residents near nuclear power plants may be using the NOAA Weather Radio warning capability in the event of radioactive leaks. As a result of the 1979 incident at the Three Mile Island nuclear plant in Pennsylvania, the Nuclear Regulatory Commission now requires operators of such plants to provide warnings to all of the people living as close as 10 miles from their sites—within 15 minutes. It is expected that some of the Nation's 100 nuclear power plants will be using the direct broadcast system in conjunction with other warning techniques such as sirens and the news media.

"Success and growth of the NOAA Weather Radio network were aided significantly through acceptance of the direct broadcast system by the various States. Some 30 States now have cooperative agreements with us to maintain local stations," said Earl W. Estelle, Chief of the Public Service Branch at the Weather Service.

According to Estelle, most States now use the broadcasts in their energy planning.

In Ohio, for example, one electric power supply co-operative monitors NOAA Weather Radio hourly for pending snow, wind, or other weather extremes that could create power outages.

During a January 1978 blizzard in Ohio, the company had planned to work all of its people through the day until downed power lines were back up. When the broadcasts revealed that much more snow was on its way, the company sent some of the people home for a break to ensure that it would have fresh personnel for the night hours.

"Without the NOAA Weather Radio information, we would have been in much worse shape during the upcoming weekend," said the company's general manager in a letter to Ed Heath, Meteorologist-in-Charge of the Akron Weather Service office.

This company encourages its customers to acquire the weather radios as a means of determining when their computer-controlled, radio-operated,

water heaters will be switched off due to excessive electrical power demand.

Another measure of the NOAA Weather Radio system's popularity is an expanding program to locate weather receivers at rest stops and tourist centers along federal highways in the various States. Weatherband receivers are currently operating at 106 stops in eight States—Delaware, Kentucky, Pennsylvania, Texas, Missouri, Minnesota, Nebraska, and North Dakota—with more planned. At least 19 other States have expressed interest in the joint project which is being conducted by the cooperating States with the National Weather Service and the Federal Highway Administration.

Pennsylvania also uses NWR receivers in their highway maintenance offices. All 67 maintenance headquarters have installed NWR to aid the planning of road work.

Another boost to the NOAA system has been the extension of the broadcasts by retransmission over cable TV. There are now hundreds of cable TV companies, serving homes throughout the Nation. This is especially important to residents of areas that are chronically threatened by severe weather.

Periodically, the National Weather Service conducts listener surveys over the NOAA Weather Radio network. One of the most recent surveys was conducted for the Hawaiian Islands by the Weather Service Forecast Office in Honolulu.

"We already knew that the most faithful listeners in Hawaii are the operators of the large sugar plantations and the commercial and sports fishermen. Cropdusting, fertilizing, irrigation, and harvesting operations in the sugar cane business depend upon the weather as much as does the fishing business," reports Clarence Lee, Meteorologist-in-Charge of the weather office in Honolulu.

"But we wanted to determine the size and constituency of the listening audience in the Islands.

"There was general approval of our products. We heard from all of the major Hawaiian Islands—Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii Island. Many listened because of their general interest in weather. Others had more specific concerns: a pilot, surfers and boaters, a cruise boat captain, and even one motorcyclist who needed to know when to pack rain gear," Lee added.

Such listener surveys always reveal that for every dramatic, lifesaving story such as the Lloyd's of Grand Island, there are thousands of testimonials about routine use of NOAA Weather Radio. Here are some quotes from letters received by weather offices as a result of other listener surveys across the country.

"The nature of our business makes it imperative that we stay constantly aware of changing weather patterns. There is no better way to keep in touch with the weather than through your service," wrote a roofing company owner in Rockford, Illinois.

"We believe that NOAA Weather Radio is extremely valuable, not only to

N.C. Dept. of Natural & Economic Resources

Small craft operators—especially those who depend upon the force of the wind—find NOAA Weather Radio a valuable aid in planning their outings.

U.S. Travel Service

Successful farming depends to such an extent on accurate and timely weather information that many formers have installed NOAA Weather Radio receivers on their farm machinery.

the rancher, farmer, and seaman, but also to the traveler and camper...particularly to the tenter who is vulnerable to extreme weather changes." wrote a couple from Whitefield, New Hampshire, who camped from Maine to Texas.

The owner of a fisherman's shop in South Carolina wrote: "We listen off and on from sunup 'til sundown. The weather broadcasts are used extensively by local fishermen who need to have up-to-the-minute information and forecasts.

"You want to know what we think of you? I can't start my day without you! I listen religiously as I get breakfast and dinner. The weather information lets me know when to set out seedlings and lime the yard, hang out winter woolens, take my granddaughter to the beach, go mulberry picking...," wrote a listener from the Maine coast.

"Our family owns six weather radios and wouldn't be without them! It's the first thing I listen to each morning and the last thing before turning out the lights at night. I have given several as gifts and my friends love them," wrote a woman from Broadwell, Illinois.

She continued:"My husband is a farmer and finds the weather radio very helpful in planning his field work. He and I also work in Springfield, 25 miles from the farm. When traveling, we also use the radio to plan when to take extra clothes in case drifting snow prevents our returning to the farm."

No listener response puts the NOAA Weather Radio system in better perspective than this Wauwatosa, Wisconsin, man: "I want to commend your agency for providing such a comprehensive weather information service to the public. It is one service that gives the taxpayers their money's worth. Thanks again."

Collision . . . and PCP in the waterway

TRACKING AN INVISIBLE MENACE

Gerald D. Hill, Jr.

A few minutes before 9:00 p.m. on July 22 two ships passing in the Mississippi River Gulf Outlet Canal collided and dumped more than 12.5 tons of pentachlorophenol (PCP) into the canal.

As a result, this major outlet to the Gulf of Mexico from New Orleans was closed to all shipping at a point 20 miles east-southeast from the port, and a large part of Louisiana's richest fishing grounds was closed to fishermen.

The 420-foot German container ship, *Testbank,* was outbound on the right side of the 500-foot wide channel; and the Panamanian ship, *Sea Daniel,* a 580-foot ore carrier was inbound on the left.

As they passed, the bow overhang of the Sea Daniel scraped down the left side of the *Testbank* damaging the containers stacked on the deck. No injuries occurred on either ship.

Of the 15 containers damaged, 6 contained dangerous cargo and one of these, containing PCP, fell into the canal. The other 5 remained on the ship but were damaged; some of their contents were either spread on the decks of the 2 ships or went into the canal. Three others containing household goods, scrap metal, and lube oil fell into the canal.

The major problem was the PCP that was lost. The other dangerous containers were packed with metacreosol,

U.S. Coast Guard

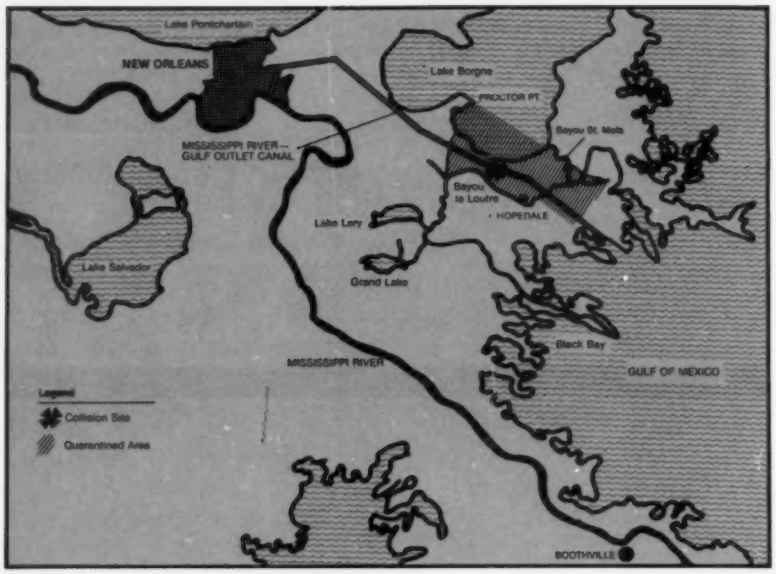
Damage to the cargo containers on the German ship, Testbank, *can be seen just aft of the central crane tower. One box—containing PCP—went over the side into the canal.*

***EDITOR'S NOTE:** NOAA scientists have worked on many oil spills, but the events in this story provided their first opportunity to be deeply involved in a chemical spill. The problems are very different. As this article was going to press, the Office of Marine Pollution Assessment was mounting a major mock chemical spill operation to test, evaluate, and improve response to such spills. NOAA magazine will carry a story on the drill in a forthcoming issue.*

hydrobromic acid, and ethyl mercaptan, none of which would enter the food chain of the area or pose any immediate danger, except to the people removing the material from the ships.

The PCP did pose a problem because of the amount that had been dumped into the water and the possibility that it would spread throughout the rich fishing area. So, in accordance with the national contingency plan, the Regional Response Team was quickly activated. NOAA became a very important part of the clean-up operation.

NOAA scientists are experienced in oil spills—the *Argo Merchant* off New England, the Campeche spill in the Gulf of Mexico, the *Amoco Cadiz* off the coast of France, and many others. The New Orleans spill was different, however, and was a new experience for them. Oil spills can be seen; scientists know where the pollutant is. Chemical



NOAA

U.S. Coast Guard

U.S. Coast Guard

Explaining spill team operations to the press (above) were Joe Colson, secretary of the Louisiana Wildlife and Fish Department, Coast Guard Captain Richard Clements, and NOAA's Will Ernst. A diver (right) prepares to search for the missing PCP container.

Well protected technicians (above) sift through material recovered from the accident scene, as a dredging barge (right) pumps the canal bottom as part of cleanup operations near the site of the container ship collision.

spills are different, at least in this case, since PCP dissolved in water is invisible and was impossible to locate by sight.

Members of the response team were lucky in one respect, in that the PCP pellets were heavier than water and dissolved slowly. The pellets settled to the bottom and tended to remain there rather than moving rapidly through the water column as some other chemcals may have done.

PCP is used primarily as a wood preservative. In this case, it was in pellet form, packed in 50-pound, 4-ply kraft paper bags. The container lost over the side originally held 720 bags. It was estimated that 200 bags from the container remained on the *Testbank* and that 20 bags were dumped on the *Sea Daniel*. The rest—25,000 pounds of PCP—had disappeared over the side in the container or had been spread along the bottom as the 2 ships moved away from each other.

At first, no one realized that the *Sea Daniel* had been contaminated and it was allowed to move into New Orleans to unload its cargo. It was later quarantined and decontaminated when bags of PCP that had burst were found spread along its deck.

Will Ernst of NOAA's Hazardous Material Response Team in Boulder, Colorado, was designated the Scientific Support Coordinator for the operation and attached to the staff of Coast Guard Captain Richard Clements, the On-Scene Coordinator.

How do you find an invisibile

substance in an area of numerous lakes, canals, and marshland? That was the riddle that faced Ernst and his team of scientists.

Ernst set up a sampling program to determine the extent of the movement of the chemical and its effect on the marine life in the area. A private laboratory was hired to test samples that were taken from the water at different depths, the sediment, and from the sea life in the area.

By plotting the location of the samples and the concentration of the PCP found at each location, the scientists were able to determine the spread of the chemical.

This technique was used to identify the areas that were closed to fishing and other aquatic activities and ultimately in opening these areas when the chemical was no longer a danger.

The owners of the ships hired a private company, Peterson Marine, Inc., to clean up the spilled contaminants and remove the damaged cargo from the ships and the canal. The owners also asked the Coast Guard to supervise and direct the activities of the cleanup crews.

The first priority was to locate and remove the spilled chemical and containers from the canal bottom. The Coast Guard used divers, magnetometers, fathometers, and side-scanning sonar to locate them.

The containers of household goods and scrap metal were found rather quickly; however, it took 9 days to find the container of PCP because it was mashed and twisted so badly that it hardly resembled its original shape. In addition, the visibility on the bottom of the canal was limited to a few inches, even with lights. The divers did most of their work on the bottom by feel rather than sight.

Divers were able to determine that bags of PCP were strewn around the site of the container and that the bags disintegrated when they were picked up. They also found that when the bags broke, the PCP pellets tended to remain in the immediate vicinity because they were heavier than water and dissolved very slowly.

Because the chemical seemed to remain in place and could not be scooped up without spreading it, it was decided that a vacuum pump would be the best way of removing the chemical from the canal bottom.

A metal tube about 10 inches in diameter was constructed and a rubber air hose was inserted in the bottom of the tube. When the air was turned on, a vacuum was formed and the material beneath the tube was forced up the tube and into a barge on the surface. A grid system was established to ensure complete coverage of the area. The material in the barge was then filtered by a system set up by the Environmental Protection Agency, which removed all of the water and suspended material from the barge. The filtered water was returned to the canal and the solid material containing the PCP was packaged and sent to a hazardous waste site in Alabama.

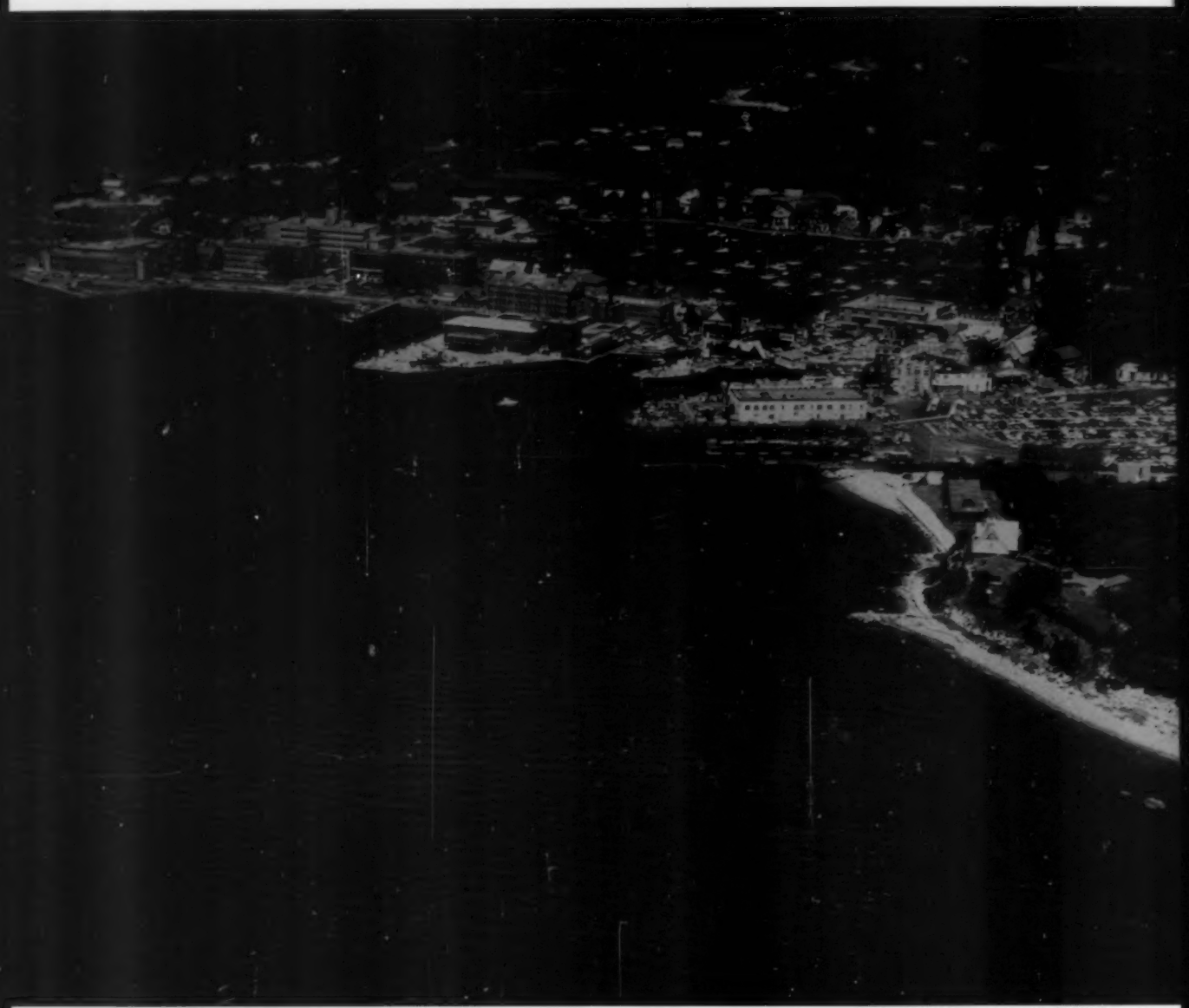
On August 10, the bottom had been cleaned of the PCP and the suction operation ended. The next day an ocean-going vessel was allowed through the area to see if it would stir up any additional PCP that may have been missed or was in the sediment of the canal bottom. Water samples were taken after the ship passed and results showed that the traces in the water were well below the safe level. The canal was opened to all traffic on August 15 and fishermen were permitted in the area soon after.

This was the biggest PCP spill ever encountered in the United States and could have been disastrous to the environment. Luckily there were no documented fish kills. The oysters that became contaminated were able to flush the chemical from their systems after the PCP was removed and they were in clean water for several days.

NOAA's sampling program continued until mid-November. The State of Louisiana is continuing the sampling program to ensure that the seafood is safe and wholesome.

The spill was costly, however. The cleanup operations alone cost about $1 million, the Port of New Orleans lost more than $3 million in revenue, and more than 400 square miles of fishing area were closed temporarily. However, because of the quick action of the Federal and State agencies involved, a potential disaster was avoided.

U.S. Coast Guard



Woods Hole Oceanographic Institution

The Next 50 Years of Research

OCEANOGRAPHERS PLOT THEIR COURSE

Vicky Cullen

Vicky Cullen is Publications and Information Manager of the Woods Hole Oceanographic Institution, Woods Hole, Mass.

Whatever the science of oceanography looks like in 2030, a half century from now, its content and its importance will depend upon the course of research set between now and then. Late in September of last year a four-day symposium at the Woods Hole Oceanographic Institution tried to lay out such a course—the research directions of oceanography on a small and local scale, on an oceanic regional scale, on a global scale, and (from a somewhat different viewpoint) on the human scale.

The consensus seemed to be that the age of exploration in oceanography is not over, that the science is moving rapidly toward important new knowledge.

At the small and local scale, for example, Dr. John M. Wood of the Freshwater Biological Institute, University of Minnesota, noted the increasing need to find out what happens to pollutants in the aquatic environment. He emphasized that, to understand the routes taken by industrial chemicals and pollutants, we need to have basic knowledge of the metabolic capabilities of the tiny organisms in the water. How do they degrade chemicals? How are their metabolic capabilities different from those of terrestrial organisms? What limitations are there on their metabolic processes? Answers to such questions as these will give us answers to critical problems of ocean and inland water contamination.

On a somewhat larger scale, problems of the coast were on the minds of several speakers. Dr. Orrin Pilkey of Duke University presented a geologist's view of the formation and life history of barrier islands, emphasizing that movement is integral to their nature. Stabilization to preserve a beach is ultimately a factor in its destruction, he said.

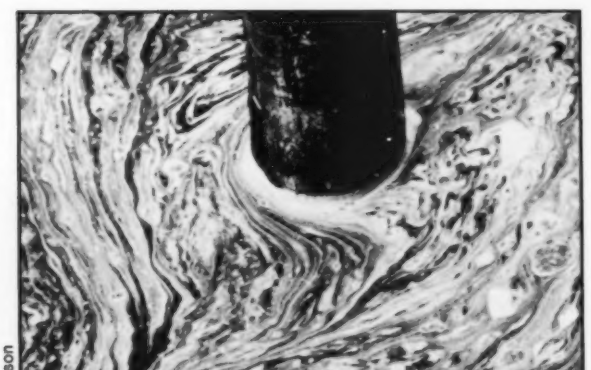
Dramatic changes offer a continuing intellectual challenge

"The North Carolina Outer Banks represent in miniature the most important practical lessons learned as a result of the intensive shoreline geological research of the last two decades," Pilkey said. "The lessons boil down to 1) barrier islands don't need human help to survive, and 2) human interference with naturally dynamic barrier island systems is actually a threat to island survival." He called for immediate steps to change present development practices on islands and for quantitative research on the controversial effects of stabilization.

Caution in increasing the demands on coastal resources was also called for by Dr. Evelyn Murphy of the Department of Urban Studies and Planning, Massachusetts Institute of Technology. "No part of the ocean is more affected by people than the coastline," she said, and called upon her listeners to play a significant role in developing the next generation of public policy for the oceans. She also urged marine scientists to take a careful inventory of coastal natural resources, "a complete, comprehensive account of the natural resources of our coast," so that coastal management policy can be based on fact rather than impressionistic argument.

"We have begun to live in an era of limits," which demands the setting of priorities, she concluded. Priority for the ocean "depends upon a much more scientifically sophisticated inventory of resources and the effects of people's use of these resources."

Dr. Walter Munk of the Scripps In-



EPA-Documerica Doug Wilson

NOAA

Meeting at Woods Hole (facing page) oceanographers examined such problems as ocean pollution (left) and its effects on the metabolic capabilities of tiny sea organisms (above).

stitution of Oceanography led off the session of the oceanic regional scale with views on needed work in acoustics and ocean dynamics. It is important to use ocean sound channels for monitoring biological, geological, and physical factors in the oceans, he said, calling for establishment of a long-term listening station for civilian use. An initial major use of such a station would be to develop a thorough understanding of "background noise" against which all acoustic measurements in the ocean must be interpreted.

The need for long-term studies was underscored by Dr. Peter Larkin of the University of British Columbia, Canada, who addressed the problems of marine fisheries and biological productivity. He observed that while the major features of oceanic ecosystems have been delineated, the dynamics within the systems remain to be understood and this knowlege will come only through long, painstaking observations and experiments.

Among other regional-scale topics considered, a paper by Drs. William Jenkins and Hugh Livingston of the Woods Hole Oceanographic Institution's Chemistry Department discussed the use of radioactive fallout from nuclear weapons testing and nuclear fuel reprocessing as tracers for the study of marine processes such as transport and sediment mixing.

As principal speaker for a panel on military and security uses of the ocean, Dr. Alan Berman of the Naval Research Laboratory reviewed the history of sea power's dependence on knowledge and application of oceanographic data. ("It is interesting to speculate on the proposition that if King Philip's Navy had even a rudimentary capability to forecast weather, or even synoptic weather information, the Spanish Armada might not have been destroyed, and the course of European and American history would have been altered substantially," Berman observed.) Panel member Rear Adm. Ross N. Williams, Oceanographer of the Navy and Naval Deputy to the Administrator of NOAA, told the assembly that many U.S. fleet ships are being outfitted with minicomputers that will help commanders interpret environmental data, and he described the National Oceanic Satellite System, a military/civilian satellite that will provide a range of remote observations and measurements beginning sometime in the mid-1980s.

The third day's session, on the global scale, began with Dr. Francis Bretherton's admonition that those interested in the climate and ocean/atmosphere system must learn to be like ducks, spending part of their time with their heads in the ocean and their feet in the air and part of their time the other way round. Bretherton is immediate past head of the National Center for Atmospheric Research in Colorado. The problems of air/sea interaction require that both oceanographers and meteorologists learn more of one another's fields, he said. (The following day Bretherton was presented by air/sea interaction colleagues with the first Bretherton Duck Award, a bobbing duck that responds to the heating of a fluid in its stand.)

Both Bretherton and Dr. Bert Bolin of the University of Stockholm, Sweden, discussed the effect on the oceans of increasing atmospheric carbon dioxide (CO_2) from the burning of fossil fuels and other sources.

Bretherton questioned whether projections of a possible climatic heating effect of the increased CO_2 take into account the transfer of heat into the oceans and consequent damping effect on the heating process. As part of his overview of global biogeochemical cycles, Bolin considered the question of whether terrestrial biota may grow more rapidly because of increasing CO_2 and discussed the relation between terrestrial and aquatic absorption of CO_2.

In a discussion of the general circulation of the oceans, Dr. Peter Niiler of Oregon State University underscored

Naval sea power's dependence on knowledge and application of oceanographic data was the subject of a panel on military and security uses of the ocean. Refueling operations are particularly dependent on accurate data.

U.S. Navy

the practical and theoretical problems of studying vertical circulation. Most available methods of measurement treat horizontal movement, and he offered possibilities for measuring or inferring vertical movement.

The principal speaker for a panel on "Ocean Science and the International Regime," Dr. Edward Miles of the University of Washington, analyzed the obligations of nations undertaking research, as defined by the current Law of the Sea negotiating text. He noted that laws of various countries will bring the policies of the negotiating text into effect even if the Law of the Sea Treaty is not ratified.

Miles observed that marine scientific research was seen by many developing countries to translate directly into capabilities of ocean use and to be a significant factor in the distribution of income derived from such use. "Access to the exclusive economic zone for the purpose of conducting scientific research, therefore, was seen to be a commodity to be traded," he said. "Consequently, extensive obligations were imposed on the researching state and all research within 200 miles was subject to the consent of the coastal state."

The symposium's final day was devoted to questions on the human scale—mineral resources of the ocean, aquaculture, and the technology of oil exploration and recovery. Dr. Abraham Lavi of Carnegie-Mellon University discussed currents, waves, and salinity gradients as potential energy sources and tapped ocean thermal energy conversion (OTEC) as the most promising. (OTEC exploits the temperature differential between upper warm layers and lower colder layers of the ocean.) However, he expressed concern about possible environmental problems caused by OTEC plants, including biofouling and increasing the average temperature of local waters, and urged careful research into these areas before any plan is put into effect. "Once the process is started," he said, "it may not be possible to stop it."

In a talk on innovative technology for ocean research, Dr. James Baker of the University of Washington discussed technology beyond ships, including microprocessors and satellites, and noted—as did other symposium speakers—that one problem in the near future will be remote sensing of vast amounts of data that will require ingenious approaches if they are to be useful rather than overwhelming.

Wrapping up the symposium were comments by officials of four United States oceanographic institutions on institutional and educational challenges facing them.

Dr. John Steele, Director of Woods Hole, opened the session with observations on the management of ocean sciences. He emphasized the need for continued flexibility in supporting different disciplines within ocean sciences that require different aproaches in management as they deal with an immense range of space and time scales. It is this breadth of scientific scale that separates oceanography from other sciences, he noted.

North Carolina's Outer Banks have provided important practical lessons in shoreline geology. One lesson: "They don't need human help to survive."

NASA

Dr. John Byrne, Vice President for Research and Graduate Education at Oregon State University, followed with a discussion of an oceanographic manpower study soon to be released by the National Academy of Sciences. The study has identified 2,600 oceanographers in the United States who hold Ph.D.'s, including 30 percent trained specifically in oceanography. There are now about 40 institutions awarding Ph.D.'s in oceanography while in 1958 there were only four. (In 1930 there were only a handful of oceanographers and no Ph.D.'s being awarded in the field.) He called attention to the fact that funding for research and development in this country is declining as a percentage of gross national product and that the number of scientists and engineers per 10,000 population shows a relative decrease in the United States, while the number is generally increasing in other countries.

Dr. Manik Talwani, Director of the Lamont-Doherty Geological Observatory, encouraged cooperation among institutions to insure the proper equipping of ocean scientists. He cited the Deep Sea Drilling Project and the submersible *Alvin* as successful national facilities and urged oceanographic institutions to pool their interests in approaching funding agencies on major equipment requests.

Dr. William Nierenberg, Director of the Scripps Institution of Oceanography, underscored the need for cooperation among institutions and disciplines both in the development of research concepts and in equipping scientists. In one sentence, he summed up the crux of oceanography in the next 50 years. "Our field is undergoing dramatic changes in policy and technology," he said, "and it offers a continuing intellectual challenge."

Break the winter woes by serving these surefire family pleasers that will have your crowd coming back for more.

Winter Wonders

HALIBUT STEAK WITH ORANGE-GRAPE SAUCE

2 pounds halibut steaks (¾-inch), fresh or frozen
2 cups boiling water
2 tablespoons lemon juice
2 teaspoon salt
1 tablespoon cornstarch
1 tablespoon sugar
½ cup orange juice
½ cup cold water
2 teaspoons grated orange rind
1 teaspoon lemon juice
1 can (11 ounces) mandarin orange segments, drained
1 cup seeded green grape halves

Thaw frozen fish, and cut into 6 serving portions. Place fish in a well-greased, large frypan. Add boiling water, lemon juice, and salt, Cover; simmer until fish flakes easily when tested with a fork, 8 to 10 minutes. While fish is cooking, prepare sauce. Combine cornstarch and sugar in small saucepan. Stir in orange rind, lemon juice, and fruits; heat. Transfer cooked, drained fish carefully to hot serving platter. Spoon sauce over halibut. Makes 6 servings.

NORTHWESTERN SALMON PIE

1 can (1 pound) salmon
1 cup salmon liquid and milk
1 cup soft bread crumbs

3 eggs, beaten slightly
1 cup diced celery
¼ cup chopped onion
2 tablespoons butter or margarine
2 tablespoons chopped parsley
1 tablespoon lemon juice
¾ teaspoon salt
1 9-inch unbaked pastry shell

Drain salmon; reserve liquid. Add milk to salmon liquid to make 1 cup. Bone, skin, and flake salmon. Combine liquids, bread crumbs, and eggs; let stand while preparing remaining ingredients. Cook celery and onion in butter or margarine until celery is tender. Add cooked vegetables, flaked salmon, parsley, lemon juice, and salt to egg mixture; mix. Pour into pastry shell. Bake in a hot oven, 400°F., 25 to 30 minutes or until crust is done and mixture is set. Let stand 8 to 10 minutes before cutting. Makes one 9-inch pie, enough for 6 servings.

PACIFIC CLAM CHOWDER

2 cups clam juice (nectar from steamed clams)
1 bouillon cube
½ cup chopped onion
½ clove garlic, minced
3 tablespoons butter or margarine
¼ cup flour
½ bay leaf
1 cup milk
1 cup drained, minced, cooked clams
1 cup drained, cooked noodles
Paprika, optional

Combine clam juice and bouillon cube; bring to a boil; stir until dissolved. Saute onion and garlic in butter or margarine until tender; stir in flour. Add clam juice and cook, stirring constantly until thick. Add bay leaf. Stir in milk, clams, and noodles; heat thoroughly. Serve in bowls; sprinkle with paprika. Makes 6 servings.

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